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P01/7700 0.00-0105160.6

02 MAR 2001

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1/77

Request for grant of a patent

The Patent Office

Cardiff Road
Newport
Gwent NP10 8QQ

1. Your reference	200-1369GB2/ORD
2. Patent application number	0105160.6 02 MAR 2001
3. Full name, address and postcode of the or of each applicant.	Land Rover Group Limited 26 New Street St Helier Jersey
Patents ADP number	7943830001
If the applicant is a corporate body, give the country/state of its incorporation	Jersey
4. Title of the invention	**A Security System**
5. Name of your agent	O. R. T. Davies et al
"Address for service" in the United Kingdom to which all correspondence should be sent.	Land Rover Patent Department Gaydon Test Centre Banbury Road, Lighthorne Warwick CV35 0RG 7689201002
Patents ADP Number	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and the or each application number.

Country	Priority application number	Date of filing
GB	0022940.1	19 September 2000

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing

8. Is a statement of inventorship and of right to grant of a patent required in support of this request.	YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	11
Claim(s)	3
Abstract	1
Drawing(s)	3 +3

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	4
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature

Owen Davies

O. R. T. Davies Agent

Date
28 February 2001

12. Name and daytime telephone number of person to contact in the United Kingdom.

O. R. T. Davies 01926 643458

Patents Form 7/77

Patents Act 1977
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The
Patent Office

7/77

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02 MAR 2001
NEWPORT

Statement of inventorship and of right to grant of a patent

The Patent Office

Cardiff Road
Newport
Gwent NP10 8QQ

1. Your reference	200-1369GB2/ORD
2. Patent application number	02 MAR 2001 0105160.6
3. Full name of the or of each applicant.	Land Rover Group Limited
4. Title of the invention	**A Security System**
5. State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent	Statutory right of employer under section 39 of the Patents Act 1977
6. How many, if any, additional Patents Forms 7/77 are attached to this form?	3
7.	I/we believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to. Signature: Owen Davies — Date: 28 February 2001 O. R. T. Davies — Agent
8. Name and daytime telephone number of person to contact in the United Kingdom.	O. R. T. Davies — 01926 643458

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Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

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DUPLICATE

A Security System

This invention relates to security systems and in particular to a security system which is arranged in use to facilitate at least one of passive access to and use of a protected area, such as a vehicle.

Passive entry and starting systems are known and allow a user to gain entry to a vehicle by simply operating a door handle and to remobilize passively and start an engine or other subsystem of the vehicle, e.g. by pressing a button. All this can be achieved by a user simply carrying a transponder about their person.

A system of this type might work, on detection of door handle operation, by sending a challenge to a remote transponder using a low frequency signal, e.g. 125 kHz. The transponder might then respond with an encrypted reply on a higher frequency, e.g. 433 MHz. The low frequency (LF) signal may be sent from coils located near the front doors and boot and further coils may be installed in the interior of the vehicle so as to establish when the transponder is inside the vehicle to facilitate engine starting. This general type of passive entry and starting system is discussed in, for example, US 4,973,958 and in EP 0783190.

It is a problem with some prior art security systems that a criminal can employ transmitter-receiver pairs with a two-way link between the vehicle and its owner. The criminal may succeed in gaining access to the car, even though the authorising transponder is not in his possession or even in range of the vehicle. One arrangement which provides protection against such so-called relay hackers is disclosed in our co-pending application GB 2332548 and its contents are hereby included in the disclosure of this application.

There are other problems associated in particular with the "passive start" of a passive entry and passive enable/start arrangement. If, for example, detectors for

passive starting rely on distance attenuation to determine whether a user is in the immediate locality of the driver's seat, it might prove difficult, due to the variability and shape of the magnetic fields, to guarantee completely reliable operation. e.g. a user carrying the transponder might be leaning against a driver's window while a child is standing on the driver's seat and this might cause the system to mistakenly determine that the conditions for enabling the starter switch had been satisfied.

It is an object of this invention to provide an improved security system.

Accordingly, the invention provides a security system comprising a plurality of signal transmitters spaced around a protected area and a portable transponder arranged in use to receive signals from said transmitters, wherein said transponder is further arranged in use to determine, from signals transmitted by said transmitters, vector information relating to the relative positioning between said transponder and said protected area.

Said vector information may comprise at least one component of the vector of a signal coming into said transponder from a said transmitter.

Said transponder may respond to a challenge signal only if the angular separation between the angular portion of said vectors falls within predetermined limits in the region of said transponder.

Said transponder may relay said vector information to a security controller of said protected area. Said transponder may relay said vector information only if the angular separation between the angular portion of said vectors falls within predetermined limits in the region of said transponder and/or only if the amplitude portion of said vectors falls within predetermined limits in the region of said transponder. Said predetermined limits may be set in accordance with the geometry of said protected area.

Said security controller may carry out a plausibility test on said relayed vector information to determine whether said transponder is positioned in a plausible relationship to said protected area. Said plausibility test may comprise a comparison between said vector information and a vector map of at least a portion of an area around said protected area. Said security controller may allow access to said protected area only if said relayed vector information passes said plausibility test.

Said transmitters may comprise at least two coils located together and in a substantially orthogonal relationship.

Said signals from said transmitters may comprise a challenge signal and said transponder may send said vector information back to the protected area included in a response signal in reply to a said challenge signal. Said response signal may include information relating to the signal strength of at least one component of said challenge signal.

Said transponder may comprise at least two coils positioned in a substantially orthogonal relationship. Said transponder may comprise a self-calibration arrangement.

Said transponder may comprise at least two hall effect transducers positioned in a substantially orthogonal relationship.

Said vector information may be used to implement at least one of a passive entry and a passive starting arrangement of a vehicle.

A vehicle including a security system according to the invention is also provided.

The invention also provides a method of enabling passive entry to a vehicle, including detecting with a portable transponder challenge signals from a plurality of vehicle mounted transmitters and determining from said challenge signals vector

information relating to the relative positioning between said transponder and said vehicle.

The invention also provides a method of enabling passive starting of a vehicle, including detecting with a portable transponder challenge signals from a plurality of vehicle mounted transmitters and determining from said challenge signals vector information relating to the relative positioning between said transponder and said vehicle.

An embodiment of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a vehicle including a security system according to the invention;

Figure 2 is a flow chart of one aspect of the operation of the system of Figure 1; and

Figure 3 is a flow chart of another aspect of the operation of the system of Figure 1.

Referring to the figures, a vehicle 10 comprises three transmitters in the form of coils A, B, C spaced around it. The coils A, B, C are located one each A, B in opposing wing mirror assemblies 12, 14 and one C in a high level brake light assembly 16 at the rear end of the vehicle 10.

The vehicle further comprises a security controller 18 which has control over vehicle access through a set of doors 20L, 20R and also has control over engine starting. The vehicle access is in the form of so-called "passive entry" and sends out a challenge signal upon an access control such as a door handle 22L, 22R being

operated. If the challenge signal is legitimately responded to with a valid and plausible response signal, the doors unlatch and allow access. In similar fashion, engine starting is also passively enabled upon pressing a starter button 24.

The challenge signal is sent out initially using the coil B nearest to the door handle 22L which has been operated or, if it is passive starting which is being attempted, by the coil B nearest to the starter switch. The challenge signal is then sent out again sequentially on at least one of the other coils A, C, the signal from each coil A, B, C being uniquely identified with the location 12, 14, 16 of that coil A, B, C.

The response signal RS, if any, to the challenge signal is provided by a portable transponder 26 which is adapted to be carried by an authorised user of the vehicle 10. The transponder 26 includes three substantially orthogonal coils X, Y, Z. These are connected via analogue switches to a single low frequency (LF) receiver, although it will be apparent that in another embodiment it would be possible to connect them instead to three LF receivers without using analogue switches.

The signal levels from each of the three transponder coils X, Y, Z are measured and are processed such that the transponder 26 determines the vector $\overline{A}$, $\overline{B}$, $\overline{C}$ of each vehicle challenge signal coming in from its respective vehicle mounted coil A, B, C, each vector comprising components x,y,z of both angle and magnitude. The vector information is sent back to the security controller 18 as an encrypted response signal, and comprises both angle and magnitude, or components x_b, y_b, z_b in which each component indicates the signal levels detected in the transponder coils X, Y, Z from the vector of the signal coming in from the vehicle coil B in question. It should be noted that the level may be a negative value and, although not absolute, one of the directions x, y, z is defined as positive, e.g. x, and that the others y, z are positive or negative depending on the sense of the signal.

The transponder 26 may be programmed to require an angular separation between the vectors $\overline{A}$, $\overline{B}$, $\overline{C}$ which is within predetermined limits, before it will send any kind of response signal RS at all. This angular separation is determined by the geometry of the vehicle 10 itself. For example, the transponder 26 would not send a response signal RS if the vector information indicated that the transponder 26 was in an implausible position such as, for example, within a fuel tank. The response signal RS includes an authentication function as well as the vector information, i.e. signal levels x, y, z.

i.e. Challenge Signal = Random Challenge

Response Signal RS = Encrypted (random challenge+vector information, e.g. x_b, y_b, z_b)

The encrypted identity may conveniently be an encrypted version of the challenge signal itself and the encryption is preferable a symmetrical algorithm having the or each encryption key stored in both the transponder 26 and in the security controller 18. The response signal is transmitted in RF and is decrypted by the security controller 18 to check that the encrypted challenge in the response signal RS matches the transmitted challenge signal and, if so, the transponder 26 is authenticated.

The vector information, in the form of the decrypted signals x, y & z, is related to the direction of reception due to the approximate cosine relation between coil orientation and incident vector $\overline{A}$, $\overline{B}$, $\overline{C}$. It will be noted, however, that this direction is defined in a frame of reference containing the transponder 26 and, as the transponder 26 may be at any orientation, this vector has no defined relationship to the vehicle 10.

Therefore, the security controller 18 can now derive this three-dimensional vector from the relative amplitudes x, y and z of the signals in the coils X, Y, Z. The angle of the vector from transmission A can be expressed as:

$\phi_A = f(x_A, y_A, z_A)$, similarly for B and C

The security controller 18 uses the vector information to determine the position of the transponder 26 in relation to the vehicle 10. In an alternative embodiment, the transponder 26 could include the logic means necessary to determine internally its position with respect to the vehicle 10 and merely relay this information back to the security controller 18. In either case, a vector map of at least a portion of the area surrounding the vehicle 10 is developed and response signals RS of vector information, or actual position as the case may be, are compared with the vector map by way of a plausibility check.

The vector information plausibility tests can benefit from increased robustness by nesting the manner in which the challenge signals are transmitted, e.g. transmit on one coil B, then transmit on both B+A and followed by A. This particular order for nesting is considered advantageous because at least some phase information is retained between the separate transmissions in the nested sequence. To this end it should be noted that, for any given set of signals received in the transponder coils X, Y and Z, there are two possible solutions for the vector which are opposite in sign. To resolve this issue, it is preferable to retain the phase information when measuring the first direction ϕ_A and to solve ϕ_B with the same phase reference.

Another or additional increase in confidence can be gained by, while listening to two coils A, B, reversing the phase on one of them and performing vector addition on the vector information in the ensuing vector signals. The resultant vector sum by which $\bar{A}+\bar{B}$ changes to $\bar{A}-\bar{B}$ allows the determination of the relative phases of vectors $\bar{A}$ and $\bar{B}$ for increased confidence in the plausibility testing.

The security controller 18 also includes in that plausibility check any additional information it may have about the transponder's likely location. For example, if the

challenge signal was initiated by operating a particular door handle 22L, the security controller 18 can assume that, for the response signal RS to pass the plausibility test, the vector information it 18 receives as a response signal RS should put the transponder 26 in the region of the vector map nearest to that door 20L.

The security controller 18 will only allow entry or remobilization if the encrypted response signal RS is correct and the angles meet criteria related to the geography of the vehicle 10.

In practice, more vehicle coils may be preferred, in order to reduce the range required from each vehicle coil A, B, C.

It may prove desirable to produce a basic version of the system, which could be implemented by for example reducing the transponder to only two coils X, Y. In this case, it is assumed that one plane of the transponder is known, e.g. by always being substantially vertical outside the vehicle (user standing) and substantially horizontal inside the vehicle (user sitting).

For a passive start application, it is preferred that the transponder 26 and the driver are both in the vehicle 10, not adjacent to it before allowing the vehicle 10 to be started. One solution would be to use specifically located interior LF coils of limited range to determine this situation. This may not prove satisfactorily reliable as the range of system components might vary, as may the presence of metal objects and other distorting factors. Use of the three orthogonal coils X, Y, Z in the transponder 26 provides substantially absolute confirmation of the location of the transponder 26 inside the vehicle 10.

Two requirements for the coils X, Y, Z may create problems. Firstly, in the interests of sensitivity, the Q of the receiver coils X, Y, Z will be high and this might lead

to variations in signal response. Secondly, to produce a preferred transponder 26 in the form of a flat "credit card"/"smart card" transponder, one of the transponder coils X, Y, Z may need to be a low profile type, also potentially leading to a varying sensitivity.

These problems may lead to a preference for including a self-calibration function in the transponder 26. This can be achieved by adding a fourth coil (not shown) which is equally spaced in angle between the other three X, Y, Z and can be used to inject a signal into the three receiver coils X, Y, Z and allow them to be calibrated. This calibration can be either used to pre-process the signals x, y & z before transmission from the transponder 26 or transmission in the encrypted response RS for use by the security controller 18 to normalise the signals.

The transponder coil assembly X, Y, Z may, for example, be embedded in a plastic or epoxy material with transponder logic circuits. This would have the advantage of excluding casual inspection or monitoring of the signals by a hacker.

The embodiment described so far relates to a system where the vehicle coils A, B, C transmit at a nominal 125kHz and the transponder 26 responds at 434MHz. Clearly, the related 315, 868 and 900 etc bands can be used. It may be found desirable to use other frequencies for the communication from the vehicle 10. For example, the use of 13.56MHz would allow a lower power transmission and a greater range. The transponder coils X, Y, Z could be changed in scale and possibly also in structure, to accommodate the change. Equally, the use of 434MHz in both directions may allow for some cost reduction in the transponder 26 due to the commonisation of the frequencies.

Hall effect sensors could be used instead of transponder coils X, Y, Z. If using a hall effect sensor for direction measurement, then data can also be sent without a carrier frequency. Use of a DC field would save the need to generate and condition AC

signals. Furthermore, hall effect transducers lend themselves better to integration in "smart card" structures than do coils.

It would also be possible to introduce a further degree of difficulty into a hacker's task by rotating the field direction from the vehicle coils A, B, C. If, for example, two orthogonal coils were both placed at a given and same location, the field vector received by the transponder 26 would vary depending on which coil is activated and this could be achieved by orientating the coils to be substantially orthogonal to each other. This additional information can be returned to the vehicle 10 and used as additional validation of direct communication with the transponder 26. Alternatively, the field direction can be modified in a pre-determined manner on a bit by bit basis as a code modulation. The transponder 26 would only respond to a correct code in this modulation.

Two examples of the operation of the system will now be discussed, with particular reference to Figures 2 and 3 for passive entry and passive starting respectively.

Referring now in particular to Figures 1 and 2, a user approaches the vehicle 10 and operates a door handle 22L. This initiates a challenge from the vehicle 10 on the coil B nearest the door 20L in question. If the transponder 26 does not receive the challenge, it is presumed that the identity of the transponder 26 does not match that of the vehicle 10.

If the identities of the vehicle 10 and the transponder 26 match, the transponder transmits back to the security controller 18 a signal in which is encrypted vector information, e.g. xyz(B).

The vehicle 10 then transmits the same or a different challenge on a different coil, e.g. coil C. The process described above is repeated, such that the transponder 26 provides the vector information xyz(C) back to the security controller 18. The vectors $\overline{B}$, $\overline{C}$ for the challenging coils B, C are then calculated and plausibility tested by comparison with a vector map to determine if the transponder 26 is within preset limits for door entry. It is during this comparison that the basic plausibility test of checking the vector map location against the door handle 22L is performed for additional security.

Referring now in particular to Figures 1 and 3, a user has gained access to the vehicle 10 and wishes to start it. On pressing the starter button 24, a challenge signal is sent by the coil B nearest the button 24. If the transponder 26 does not receive the challenge, it is presumed that the identity of the transponder 26 does not match that of the vehicle10.

If the identities of the transponder 26 and the vehicle 10 match, the transponder 26 transmits back to the security controller 18 a signal in which is encrypted vector information, e.g. xyz(B).

The vehicle 10 then transmits the same or a different challenge on a different coil, e.g. coil A. The process described above is then repeated, such that the transponder 26 provides the vector information xyz(A) back to the security controller 18. The vectors $\overline{B}$, $\overline{A}$ for the challenging coils B, A are then calculated and plausibility tested by comparison with a vector map of the vehicle interior so as to determine whether the transponder 26 is within the preset limits for remobilization and/or engine starting. During this phase of passive remobilization, it may prove advantageous to additionally include further sensing arrangements, such as seat mounted weight sensing, for further robustness before starting an engine.

CLAIMS

1. A security system comprising a plurality of signal transmitters spaced around a protected area and a portable transponder arranged in use to receive signals from said transmitters, wherein said transponder is further arranged in use to determine, from signals transmitted by said transmitters, vector information relating to the relative positioning between said transponder and said protected area.

2. A security system according to Claim 1, wherein said vector information comprises at least one component of the vector of a signal coming into said transponder from a said transmitter.

3. A security system according to Claim 1 or Claim 2, wherein said transponder responds to a challenge signal only if the angular separation between the angular portion of said vectors falls within predetermined limits in the region of said transponder.

4. A security system according to any preceding claim, wherein said transponder relays said vector information to a security controller of said protected area.

5. A security system according to Claim 4, wherein said transponder relays said vector information only if the angular separation between the angular portion of said vectors falls within predetermined limits in the region of said transponder.

6. A security system according to Claim 4 or Claim 5, wherein said transponder relays said vector information only if the amplitude portion of said vectors falls within predetermined limits in the region of said transponder.

7. A security system according to Claim 5 or Claim 6, wherein said predetermined limits are set in accordance with the geometry of said protected area.

8. A security system according to any one of Claims 3 to 7, wherein said security controller carries out a plausibility test on said relayed vector information to determine whether said transponder is positioned in a plausible relationship to said protected area.

9. A security system according to Claim 9, wherein said plausibility test comprises a comparison between said vector information and a vector map of at least a portion of an area around said protected area.

10. A security system according to Claim 8 or Claim 9, wherein said security controller allows access to said protected area only if said relayed vector information passes said plausibility test.

11. A security system according to any preceding claim, wherein said transmitters comprise at least two coils substantially located together in an orthogonal relationship.

12. A security system according to any preceding claim, wherein said signals from said transmitters comprise a challenge signal and said transponder sends said vector information back to the protected area included in a response signal in reply to a said challenge signal.

13. A security system according to Claim 12, wherein said response signal includes information relating to the signal strength of at least one component of said challenge signal.

14. A security system according to any preceding claim, wherein said transponder comprises at least two coils positioned in a substantially orthogonal relationship.

15. A security system according to any preceding claim, wherein said transponder comprises a self-calibration arrangement.

16. A security system according to any one of Claims 1 to 13, wherein said transponder comprises at least two hall effect transducers positioned in a substantially orthogonal relationship.

17. A security system according to any preceding claim, wherein said vector information is used to implement at least one of a passive entry and a passive starting arrangement of a vehicle.

18. A security system substantially as described herein and with reference to the accompanying drawings.

19. A vehicle including a security system according to any preceding claim.

20. A method of enabling passive entry to a vehicle, including detecting with a portable transponder challenge signals from a plurality of vehicle mounted transmitters and determining from said challenge signals vector information relating to the relative positioning between said transponder and said vehicle.

21. A method of enabling passive starting of a vehicle, including detecting with a portable transponder challenge signals from a plurality of vehicle mounted transmitters and determining from said challenge signals vector information relating to the relative positioning between said transponder and said vehicle.

ABSTRACT (Fig. 1)

A Security System

A security system is disclosed which is suitable for use in a passive entry and passive starting arrangement for a vehicle 10. A set of transmitters in the form of coils A, B, C are spaced around the vehicle 10, one A, B in each door mirror 20R, 20L and one in a high level brake light 16 at the rear end.

Operation of a door handle initiates an access challenge from the vehicle 10 which is sent out successively on a plurality of the coils A, B, C. A portable transponder 26 carried by an authorised user is adapted to pick up the challenge signal and send back to a security controller 18 a response signal in which is included vector information relating to the relative positioning between the vehicle 10 and the transponder 26.

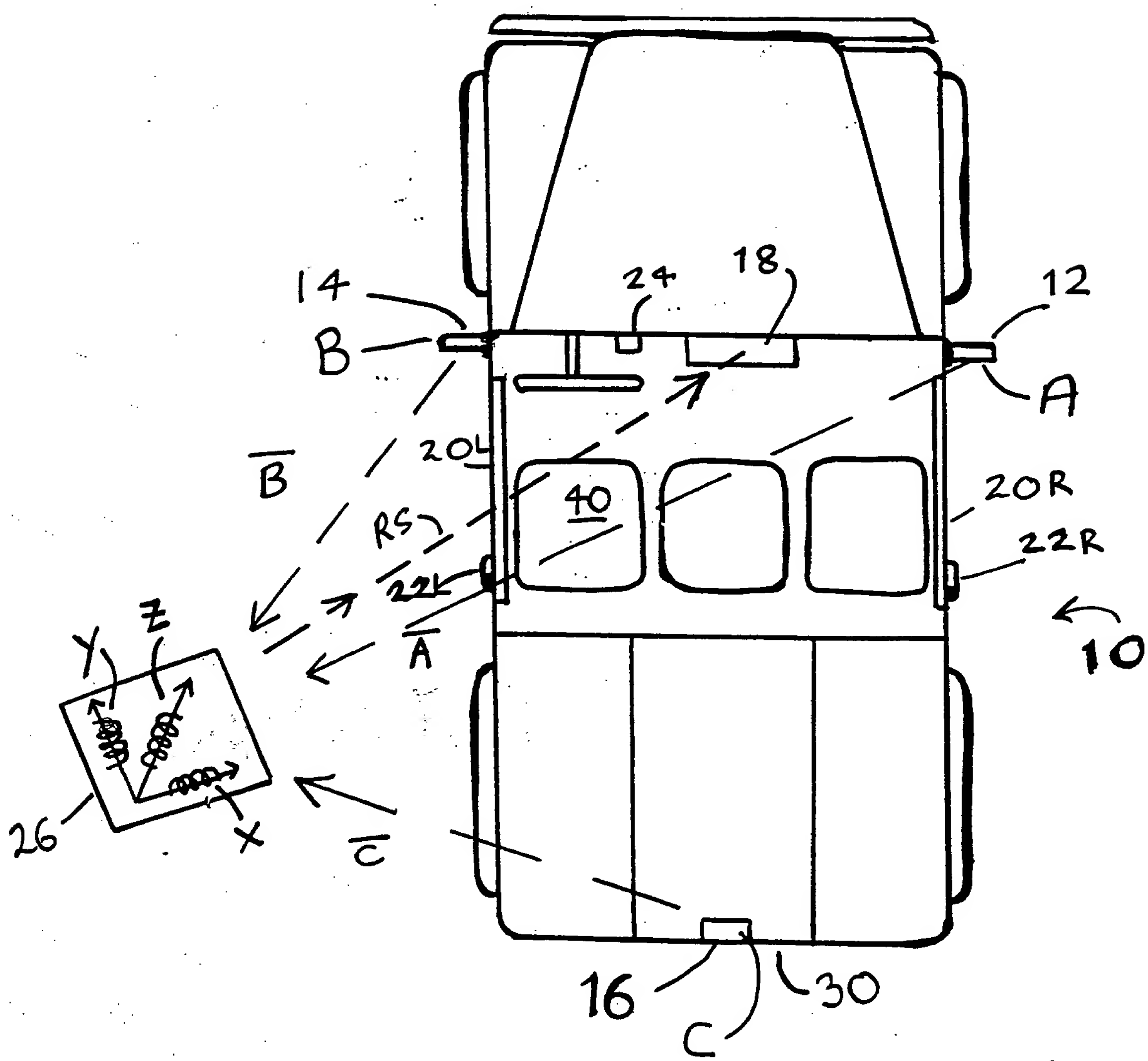
14
24
18
12
B
A
20L
$\overline{B}$
20R
40
RS
22R
22L
10
Y
Z
$\overline{A}$
26
X
$\overline{C}$
16
30
C

Fig. 1

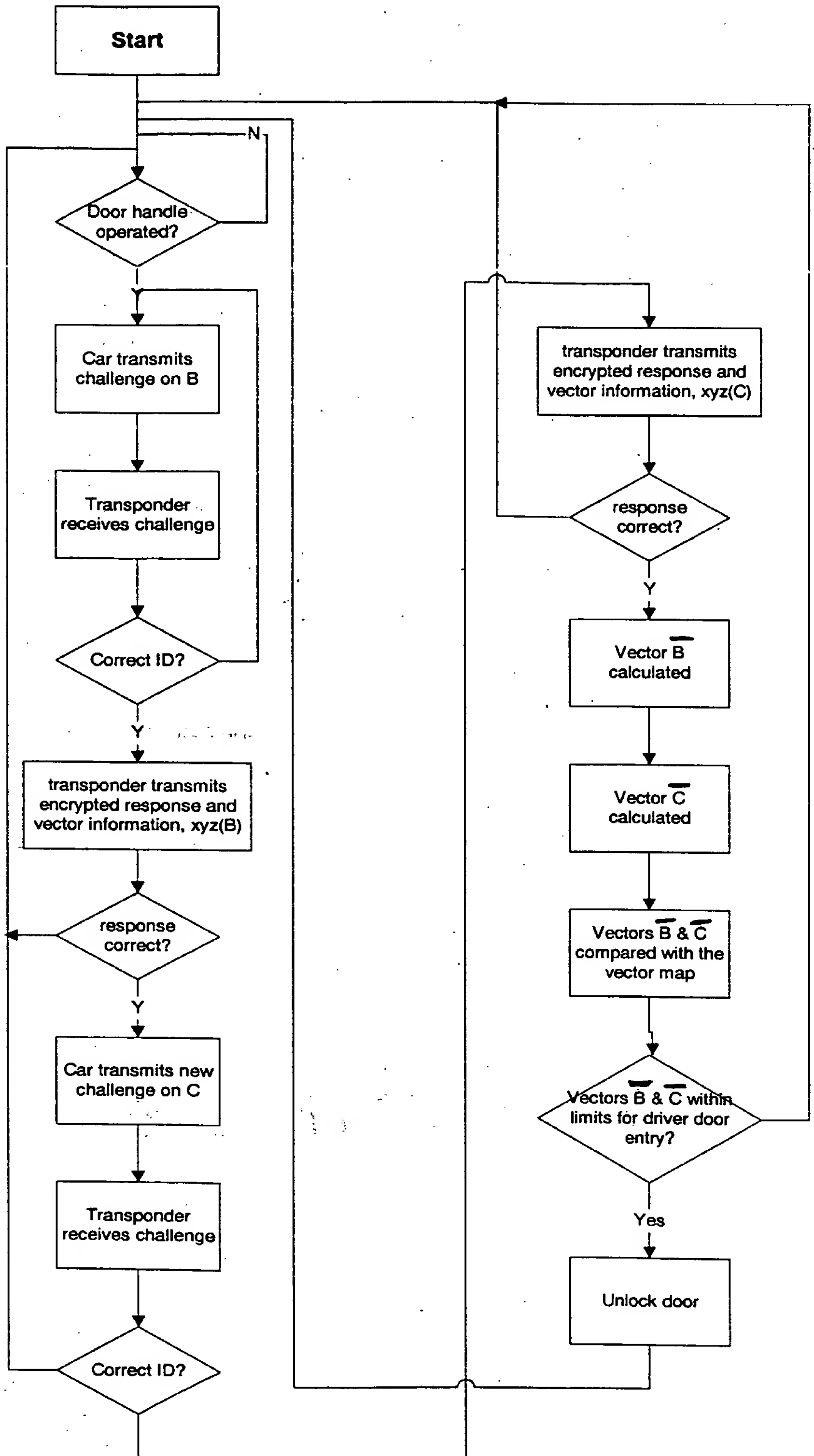

Fig. 2

Typical Response To Operation from Door.

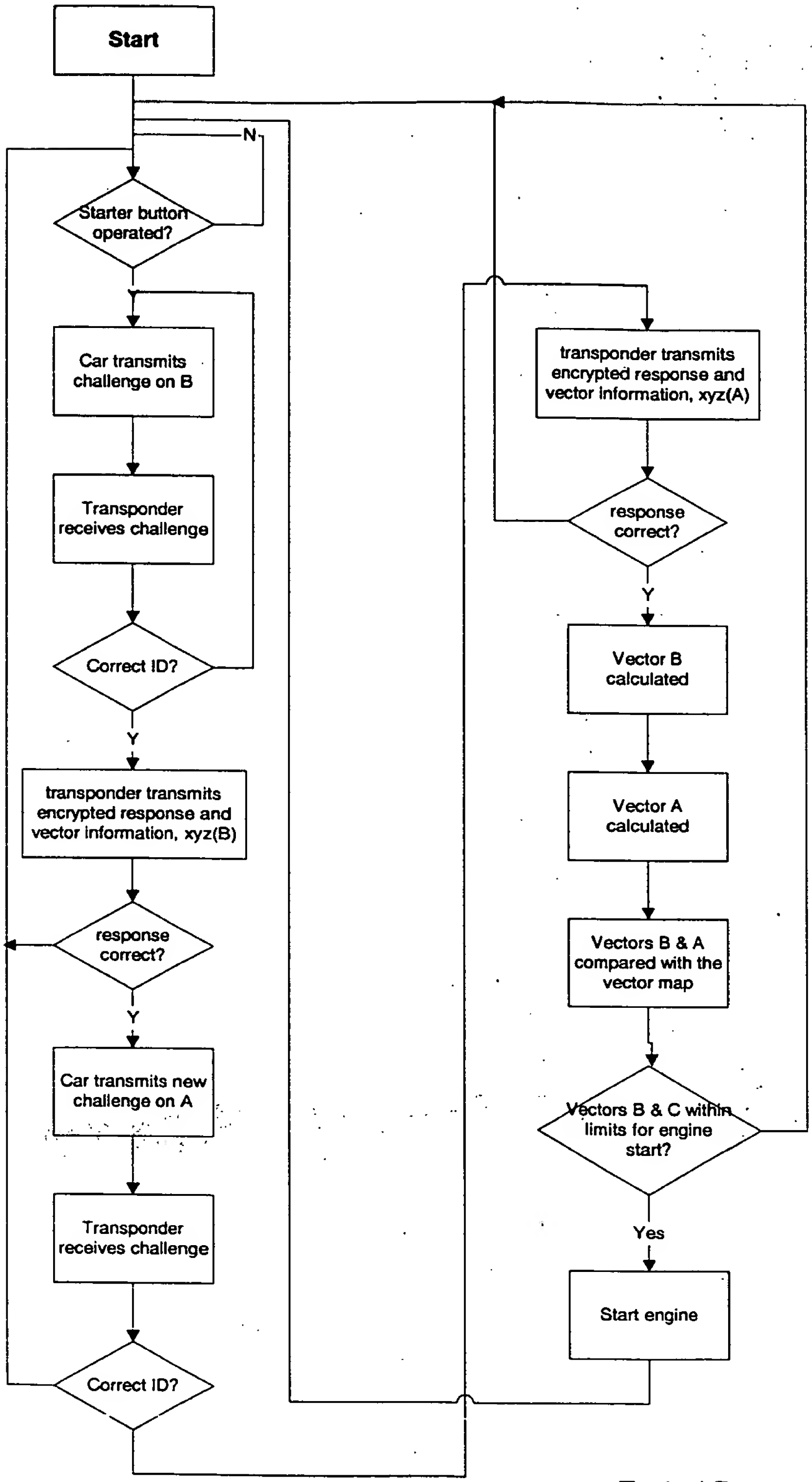

Fig. 3

Typical Response To Operation from Engine Start Button.